Role of Modeling in the Development of Interim Guidelines for the Operation of Lake Powell and Lake Mead

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INTRODUCTION

The Bureau of Reclamation (Reclamation) is the agency designated to act on behalf of the Secretary of the United States Department of the Interior (Secretary) with respect to the operation of Lake Powell (Glen Canyon Dam) and Lake Mead (Hoover Dam) on the Colorado River. Lake Powell and Lake Mead have a combined capacity of over 50 million acre-feet (maf), and when combined with the other 10 mainstem reservoirs, the overall storage capacity is four times the average natural flow of the Colorado River (15 maf over the past 100 years). The Colorado River system provides water to approximately 30 million people and is used to irrigate approximately 3 million acres.

Reclamation is faced with the problem of limited water supplies and increasing demand in the fastest growing region in the country. The major challenge is to meet the demands of a diverse group of stakeholders comprised of state agencies, Native American tribes, irrigation districts, municipalities and other non-governmental organizations with often conflicting interests such as municipal, industrial, and agricultural supply, hydropower production, recreation, endangered species and other environmental concerns. These issues are intensified by the extreme hydrologic variability that is characteristic of the Colorado River. During the period of 2000 through 2007, the Colorado River Basin experienced the worst drought conditions in approximately one hundred years of recorded history. Currently, the Department of the Interior does not have specific operational guidelines in place to define the circumstances under which the Secretary would reduce the annual amount of water available for consumptive use from Lake Mead nor to address the coordinated operations of Lake Powell and Lake Mead, particularly during drought and low reservoir conditions.

Controversy has been synonymous with the Colorado River since the signing of the Colorado River Compact in 1922, negotiated during a period of relatively high flows. Accompanying the drought beginning in 2000 was increased tension among the Lower Division states (Arizona, California and Nevada), the Upper Division states (Colorado, New Mexico, Utah and Wyoming), and other stakeholders including recreational and power interests as the levels of Lake Powell and Lake Mead dropped. In May of 2005, Secretary Norton directed Reclamation to engage in a process to develop additional operational guidelines for Lower Basin shortages and the operation of Lakes Powell and Mead under low reservoir conditions.

In the fall of 2005 Reclamation announced the intent to initiate a National Environmental Policy Act (NEPA) review process. This process is near completion with the publishing

of the Final Environmental Impact Statement (EIS) for Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead on target for the end of September and the Record of Decision anticipated to be issued in December. Computer modeling has played a central role in developing and analyzing the EIS alternatives as well as selecting the Preferred Alternative.

Reclamation uses modeling extensively for planning purposes to represent the complex system of reservoir operations in the Colorado River basin. Reclamation's official hydrologic planning model, the Colorado River Simulation System (CRSS), is a necessary component of long-term planning and policy studies. The exploration of alternative reservoir operating polices and the assessment and review of existing policies using modeling is essential to ensure that operations can respond to the changing hydrologic conditions and management objectives on the river.

MODELING

In addition to performing planning studies to inform decision-makers, a model facilitates communication and understanding of the policies between stakeholders and water managers. A variety of modeling systems are available to water management agencies and stakeholders although often they do not offer the flexibility required to mimic the changing multiple objectives of water projects and require significant effort and expense to maintain and update (Zagona et al., 2001).

RiverWare

Reclamation utilizes RiverWare™ that overcomes these shortcomings by its flexible policy expression and the extensive library of physical processes algorithms (Zagona et al., 2001). RiverWare™ is a computer software package developed by the University of Colorado Center for Advanced Decision Support for Water and Environmental Systems (CU-CADSWES). RiverWare™ was developed with the intention of meeting the needs of water management agencies in replacing obsolete site-specific models. It is a generalized river basin modeling tool than can be applied to a river basin of interest for operations and planning purposes (Zagona et al., 2001). RiverWare™ is visually oriented and displays and represents the physical river system using a series of predefined objects such as reservoirs, river reaches, canals, etc. These objects are linked together and information is propagated between them via the links when a simulation is performed.

Official River Operations Model CRSS

CRSS is Reclamation's designated monthly timestep model used to simulate reservoir and river operations in the Colorado River Basin. It was originally developed in the 1970's and 80's as a FORTRAN program. In the mid-1990's, Reclamation re-implemented CRSS in RiverWare, with involvement of interested stakeholders. The *Law of the River* and other operating criteria are expressed as logical rules in RiverWare's rule language that can be understood and modified to meet changing objectives in the basin and are isolated from the physical process model. The RiverWare Policy Language

(RPL), viewed and modified outside of compiled code, allows the specification of logical "if-then-else" or "while" statements, and other customized functions to represent policy. The ability of this language to capture significant detail is demonstrated by its ability to capture the complexity of the operational policies in CRSS. The policy ruleset drives the simulation by setting values on variables within objects on the workspace. The objects then solve their hydrologic equations according to the stored values.

The RiverWare™ version of CRSS is now the officially accepted version of the model. The process of implementing CRSS in RiverWare™ clarified many policies not documented in the FORTRAN version and was crucial in providing the foundation upon which new policies can be added. The flexibility of RiverWare™ has made possible model studies for long-term planning, mid-term forecasting and short-term scheduling and Reclamation now has a variety of RiverWare-based models in use throughout its Regional and Area offices in the Colorado River Basin.

Long-Term Planning Studies

Long-term planning studies examine the effects of changes on the river system – new or modified structures, change in hydrology or climate, changes in water use and demands, and changes in operating procedures. Since the enactment of NEPA in 1969, proposed major federal actions that may significantly affect the quality of the human environment must undergo analysis to assess the potential environmental impacts associated with the proposed action and those effects are disclosed prior to implementation. These studies pursuant to NEPA necessitate long-term planning model runs that compare several operating policy alternatives and their potential impacts. At the initiation of a NEPA process, public scoping is conducted to solicit input from the public and inform the identification of key issues and potential alternatives to be addressed in the study. The selected alternatives are modeled in CRSS to assess potential impacts to the various resources. Examples of completed long-term planning studies include the Interim Surplus Criteria EIS and the Lower Colorado Multi-Species Conservation Plan (Fulp and Harkins, 2001).

Due to the potential wide-ranging effects of these impacts, the time-horizon over which the model is run is on the order of decades. Different operating policies are implemented in separate rulesets, which are interpreted by RiverWare™ when the model is run. Model output is managed and presented using Riverware's Graphical Policy Analysis Tool (GPAT) jointly developed by CU-CADSWES and Reclamation. GPAT presents the output from several RiverWare simulations in graphical comparative figures allowing the impacts of policy alternatives to be fully explored (Wheeler et al., 2002).

STAKEHOLDER INVOLVEMENT

Colorado River stakeholders were directly and substantially involved in the development of the EIS alternatives. These major stakeholder groups are Cooperating Agencies (Bureau of Indian Affairs, US Fish and Wildlife Service, National Park Service (NPS), Western Area Power Administration (Western) and the United States Section of the

International Boundary and Water Commission), the seven Basin States, Indian Tribes and a consortium of environmental non-governmental organizations (NGOs).

Anticipating this high stakeholder involvement, Reclamation developed, in collaboration with CU-CADSWES, a RiverWare™ model referred to as CRSS-Lite (Lite). Lite was designed to provide a faster, less complex alternative to CRSS for the purpose of screening policy alternatives, policy evaluation and comparing the results of different operations in the Lower Basin and at Lake Powell (Jerla, 2005). A group of stakeholders established the initial user-requirements and were kept actively engaged in the development process. Reclamation worked individually with the Cooperating Agencies, Basin States and NGOs over the course of two years providing technical assistance. Lite was the principal modeling tool and during this time some 200 different operating scenarios were modeled and analyzed. Lite and CRSS are highly credible tools in the stakeholder community for modeling Colorado River Basin study efforts.

In July 2005 and then updated in July 2006, the NGOs submitted their "Conservation Before Shortage" proposal. In February 2006 (and reaffirmed in April 2007) the Basin States submitted a "Preliminary Proposal Regarding Colorado River Operations" in a letter to the Secretary. Through this proposal the Basin States reached a consensus for the first time in history on issues of this magnitude. Additionally, a third operational strategy was modeled and developed in coordination with the NPS and Western. All three strategies were included among the alternatives analyzed in the EIS.

REFERENCES

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NOTES FROM THE PRESENTATION

The above paper was provided as background material for participants in advance of the workshop. Additional detail was provided during the presentation and in through the discussion that followed. Included were the following topics:

- Who were the "stakeholders," "water managers" and "decision makers"?
- The "RiverWare™ version of CRSS is now the officially accepted version of the model." Did all stakeholders and agencies accept this model's outputs? How was this trust in the model created?
- What was the role of the public engagement (scoping) in the model development process? How did the public contribute to the model?
- The difference between the full version and the "Lite" version was the timestep (monthly vs. annual). Did participants voice concern about this loss of resolution?
- BuRec worked with modelers from Cooperating Agencies, Basin States and NGOs individually and supported the groups in the development of their preferred alternatives. How important was the communication between stakeholder groups about the alternatives they were developing? Were planning objectives specified and evaluated against performance measures, or did the modeling reveal critical performance measures that were used to label one alternative better than another?
- What were the opportunities for collaborative learning of each others' positions, values or concerns?